1539

Influence of Variety, Storage and Maturity on the Quality of Canned Apple Slices[1, 2]

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Apple slices are an important canned commodity in the United States. About 4 to 5 million bushels of apples are used annually for canned slices. Slice processing is concentrated in three sections of this country; the Central Appalachian area, which comprises parts of Maryland, Pennsylvania, Virginia and West Virginia; New York State; and the Pacific coast states of California, Oregon and Washington. The Appalachian area and New York State now produce about 80 per cent of the total slice pack (3).

This paper presents the results of a two year slice study for Stayman, Golden Delicious, York Imperial, Rome Beauty, and a one year study of Northwest Greening and Jonathan, all important apple varieties in the Appalachian area. The objectives of this work were: to ascertain the effects of variety, storage duration, storage type (cold or common) and maturity on the quality of canned apple slices; to determine the relationships between the physical characteristics and chemical constituents of the raw apple and the quality of canned slices; to determine if one or more raw product tests can be used to predict the canned slice overall grade; and to ascertain those factors of slice quality which have the greatest influence on the overall grade.

Materials and Methods

1955–56 Season

Raw product handling—Stayman, Golden Delicious, York Imperial, Rome Beauty, and Northwest Greening varieties were studied in the fall of 1955. Eighteen bushels of apples, 2½ to 3 inches in diameter, were harvested from 20 representative trees at what was regarded as an optimum picking maturity. Maturity levels are shown in Table 1.

Two bushels of each variety were processed and analyzed immediately after harvest. The remainder were separated into two equal quantities. One lot was stored at 34°F and the other in a common storage room. The common storage room was ventilated automatically whenever the outdoor temperature dropped more than 3°F below the room temperature. At temperatures below 30°F, ventilation was stopped to protect the fruit from freezing. Temperature and humidity were recorded in common storage and the temperature summations in degree-days above 30°F calculated.

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Table 1.—Description of mean maturity levels of raw apples at harvest (1955).

Variety	Shear press (lbs. force)	Titratable acidity	Soluble solids	Ascorbic acid (mg/100 gms)
		per cent	*per cent*	
Stayman	678	0.61	10.6	12.54
Golden Delicious	596	0.39	12.2	7.33
York Imperial	757	0.43	8.5	7.91
Rome Beauty	704	0.31	11.1	6.26
Northwest Greening	1077	0.48	6.2	8.92

Apples were removed from the storages, for processing and analysis, on the basis of 25, 50, 75, and 100 per cent of their average expected storage life. Storage intervals between sampling days and total storage periods are shown in Table 2.

Laboratory procedures—Forty apples were selected at random from each two bushel group. Pressure tests using a Magness and Taylor tester, $^{7}/_{16}$″ dia. were made at 3 points on each apple (4). A random 150 gram sample of peeled, cored, and trimmed slices from the 40 apples, was placed in the standard Maryland shear-press 10 blade-grid cell, with the slices at right angles to the blades. Shearing speed was adjusted to a setting of 4 on the flow control valve.

Table 2.—Description of storage intervals and storage periods (1955).

Variety	Storage interval between sampling (days)		Total storage period (days)	
	Cold	Common	Cold	Common
Stayman	33	16	132	64
Golden Delicious	26	14	104	56
York Imperial	33	20	132	80
Rome Beauty	33	20	132	80
Northwest Greening	33	20	132	80

Titratable acidity using phenolphthalein, ascorbic acid using indophenol dye, pH, soluble solids, total solids, alcohol-insoluble solids (AIS), total, acid soluble and water soluble pectins, expressed as anhydrogalacturonic acid (1), (6), total sugars (5), and sugar-acid ratio were determined on each lot prior to processing. Skin color was determined by rotating 10 apples over the viewing head of the Hunter Color and Color Difference meter using a red plate with the assigned values of: $L = 26.6$, $a_L = +26.7$, $b_L = +12.9$.

Pilot plant procedures—After machine peeling and coring, the raw apples were immediately trimmed, sliced and placed in a 3 per cent NaCl solution. The slices were than flushed with cold water in screened blanching baskets and placed in a processing retort adapted for vacuum. The slices were subjected to 28″ dry vacuum for 3 minutes. The vacuum was then broken with steam, the steam pressure brought up to 7 p.s.i. and held for 20 seconds. The steam pressure was released and the slices were removed from the retort.

Two hundred grams of hot slices, 1 oz. of sugar and 75 gms. of

200°F water were filled into No. 1 plain side, enameled end tin cans. The cans were sealed, immediately processed in boiling water for 10 minutes, cooled and stored at room temperature.

Organoleptic evaluations—Canned slices were evaluated organoleptically for the various quality factors by representatives from industry, Agricultural Marketing Service inspectors and local technologists. Each panel member evaluated the slices first from the overall grade standpoint considering the factors of flavor, color, wholeness and firmness. Then using a 10 part scale, with 1 thru 5 being standard and 6 thru 10 fancy quality, the samples were scored for the above individual quality factors.

Statistical evaluation—Statistical procedures were used according to Snedecor (7). An unpublished method by Amihud Kramer of this department was used for determination of partial regression coefficients.

1956–57 Season

Raw product handling—The Northwest Greening variety was dropped because of poor quality and the Jonathan variety was added. The apples were harvested, stored and sampled as described for 1955–56 except that all varieties were picked at three stages of maturity, pre-optimum (early harvest), optimum (medium harvest) and post-optimum (late harvest). Maturity levels at harvest are shown in Table 3.

Table 3.—Description of mean maturity levels of raw apples at harvest (1956).

Variety	Picking time	Shear-press (lbs. force)	Titratable acidity	Soluble solids	Ascorbic acid (mg/100 gms)
			per cent	*per cent*	
Stayman	Early	580	0.70	11.2	11.03
	Medium	555	0.71	13.6	13.84
	Late	438	0.65	16.5	4.89
Golden Delicious	Early	595	0.53	13.5	7.03
	Medium	467	0.55	15.8	10.54
	Late	362	0.47	15.5	10.20
York Imperial	Early	672	0.52	11.1	9.73
	Medium	569	0.54	11.9	8.94
	Late	485	0.43	13.5	6.24
Rome Beauty	Early	650	0.40	13.2	8.27
	Medium	460	0.33	12.5	5.81
	Late	435	0.27	12.3	4.49
Jonathan	Early	601	0.99	11.8	11.97
	Medium	626	0.80	14.8	13.77
	Late	533	0.76	14.9	13.12

Storage intervals for all varieties except Jonathan are shown in Table 2. The Jonathan samples were held 24 days between cold storage periods, and 13 days between common storage periods. Total storage was 96 days in cold and 52 days in common.

Laboratory and pilot plant procedures—Both were carried out as in 1955–56 except the raw apple weight losses in common and cold storage were also determined.

Organoleptic evaluations—Evaluations used in 1955–56 were continued in 1956–57 except a plus or minus scale was used to measure the firmness of the canned slices in 1956–57. The scale was as follows: +4 inedible, +3 much too firm, +2 too firm, +1 slightly too firm, 0 ideal firmness, −1 slightly too soft, −2 too soft, −3 much too soft, −4 mush.

Results and Discussion

Changes that occurred in the raw apples and the resulting quality evaluation of the canned slices are reported in Tables 4–12. These are necessarily mean values. Laboratory analyses are in many cases duplicate and triplicate values. Some of the physical tests represent 10–120 observations. For the canned slices scores of approximately 15 judges were pooled for analysis. It was impossible because of the great number of analysis to report all significant interactions which occurred. Some of the information presented in the tables is well known, but is included as reference material for this study. No attempt will be made to discuss each treatment in detail; only pertinent results are presented.

Variety effect—Results of the variety effect on physical characteristics, chemical constituents of raw apples and canned slice quality for two seasons are presented in Tables 4, 5, and 6. These are mean values for each variety including all maturities, storage types and storage durations. In the 1955–56 season each mean value includes 9 treatments and in the 1956–57 season, 15 treatments.

Raw apples—There were definite differences in firmness among the varieties measured by the pressure tester and shear-press. York Imperial and Northwest Greening were very firm at time of harvest and remained this characteristic in storage. Jonathan remained firm in cold storage, but did not hold up satisfactorily in common storage. Stayman and Golden Delicious were quite soft, especially the Stayman held in common storage.

Tartness and acidity of the Jonathan and Stayman were high.

There were slight differences between the two seasons in amounts of AIS and pectic constituents in the varieties. Generally Stayman, York Imperial and Northwest Greening contained the greatest amounts of AIS and total, acid and water soluble pectins. This was an example of both firm and soft textured varieties having about the same amounts of pectic constituents. Total pectic constituents for the varieties under study ranged from 0.35 to 0.65 per cent on a fresh weight basis. The pectic content of the raw apple was considered to affect both the wholeness and firmness of the canned slices.

Stayman and Golden Delicious were highest in total solids, sugars and soluble solids. In 1956–57 Stayman showed total solids readings as high as 18.5 per cent. Rome Beauty was low in total solids, sugars and soluble solids. Golden Delicious and Rome Beauty as raw apples generally showed sugar-acid ratios of 40 and above. Jonathan and Northwest Greenings had sugar-acid ratios of around 20 which were very tart.

Table 4.—Effect of variety on physical characteristics, chemical constituents (fresh weight basis) of raw apples, and on canned slice quality—(1955–56 season).

Variety	Pressure test (lbs.)	Shear-press (lbs. force)	pH	Titratable acidity (per cent)	Ascorbic acid (mg./100 gms.)	Soluble solids (per cent)	Total sugars (per cent)	Total solids (per cent)	AIS (per cent)	Total pectins (per cent)	Acid-soluble pectins (per cent)	Water-soluble pectins (per cent)
Stayman	12.80	330.2	3.35	0.52		14.2	12.68	16.66	2.69	0.442	0.280	0.161
Golden Del.	12.90	337.0	3.61	0.36		13.9	12.10	15.48	2.48	0.471	0.317	0.154
York Imp.	17.51	499.6	3.37	0.38		12.9	11.62	15.62	2.85	0.503	0.343	0.160
Rome Beauty	14.91	398.8	3.43	0.29		11.4	10.06	13.29	2.13	0.342	0.223	0.119
N.W. Greening	22.37	749.5	3.51	0.49		10.2	9.30	13.42	2.92	0.583	0.375	0.207
L.S.D. 5% level	1.16	56.5	0.03	0.04	N.S.	1.0	0.82	0.80	0.21	0.052	0.042	0.017
L.S.D. 1% level	1.60	77.8	0.04	0.06	N.S.	1.4	1.12	1.11	0.29	0.072	0.059	0.023

Variety	Sugar-acid ratio	Skin color Hunter L	Skin color Hunter ^{a}L	Skin color Hunter $+^{b}L$	Trim, core peel losses (per cent)	Color canned slices	Wholeness canned slices	Firmness canned slices	Flavor canned slices	Overall quality canned slices
Stayman	28.52	32.3	+20.09	9.4	29.9	5.7	4.6	5.5	6.6	5.4
Golden Del.	40.66	73.8	−11.85	36.2	29.4	7.7	7.7	7.4	7.2	7.2
York Imp.	32.91	47.6	+14.21	16.6	32.2	6.8	7.7	7.4	7.0	6.9
Rome Beauty	41.16	43.9	+10.16	17.0	27.5	6.1	7.6	6.2	6.4	5.8
N.W. Greening	20.84	63.2	−17.39	29.2	33.8	2.1	6.3	5.3	4.7	2.9
L.S.D. 5% level	3.95	2.9	2.48	1.7	0.7	0.5	0.4	0.3	0.3	0.4
L.S.D. 1% level	5.45	4.1	3.42	2.3	1.0	0.6	0.5	0.4	0.4	0.5

Table 5.—Effect of variety on physical characteristics, chemical constituents (fresh weight basis) of raw apples, and on canned slice quality—(1956–57 season cold storage.)

Variety	Pressure test (lbs.)	Shear-press (lbs. force)	pH	Titratable acidity (per cent)	Ascorbic acid (mg./100 gms.)	Soluble solids (per cent)	Total sugars (per cent)	Total solids (per cent)	AIS (per cent)	Total pectins (per cent)	Acid-soluble pectins (per cent)	Water-soluble pectins (per cent)
Stayman	13.01	289.0	3.46	0.61	4.92	16.02	11.19	18.50	3.10	0.647	0.504	0.144
Golden Del.	12.38	275.0	3.76	0.42	5.29	15.47	10.63	17.31	2.58	0.447	0.294	0.152
York Imp.	16.16	381.0	3.54	0.40	4.36	13.64	10.31	15.84	2.56	0.517	0.376	0.141
Rome Beauty	13.73	283.0	3.61	0.30	3.44	13.11	9.22	14.56	2.47	0.471	0.370	0.113
Jonathan	14.72	378.0	3.37	0.77	5.73	14.56	9.62	16.55	2.53	0.423	0.273	0.149
L.S.D. 5% level	0.71	12.0	0.02	0.02	0.73	0.52	0.35	0.34	0.13	0.057	0.065	0.020
L.S.D. 1% level	0.95	16.0	0.03	0.03	0.98	0.70	0.46	0.46	0.17	0.077	0.088	0.027

Variety	Sugar-acid ratio	Skin color Hunter L	Skin color Hunter $+^{a}L$	Skin color Hunter $+^{b}L$	Trim, core peel losses (per cent)	Weight loss storage (per cent)	Color canned slices	Wholeness canned slices	Firmness canned slices	Flavor canned slices	Overall quality canned slices
Stayman	27.08	38.8	+13.8	+ 7.4		3.19	6.6	5.9	7.3	6.1	5.7
Golden Del.	38.87	74.1	−17.8	+30.9		2.95	6.9	7.2	7.9	6.4	6.4
York Imp.	36.04	51.0	+ 9.3	+15.3		1.74	7.5	8.1	8.4	6.5	7.0
Rome Beauty	47.65	47.7	+10.9	+14.9		1.51	5.9	6.6	7.3	5.6	5.6
Jonathan	19.50	41.6	+12.5	+13.8		1.87	6.8	7.4	8.5	5.8	6.2
L.S.D. 5% level	3.01	2.7	2.4	1.3	N.S.	1.17	0.7	0.4	0.7	0.4	0.7
L.S.D. 1% level	4.05	3.6	3.3	1.8	N.S.	N.S.	0.9	0.7	1.0	0.6	0.9

Table 6.—Effect of variety on physical characteristics, chemical constituents (fresh weight basis) of raw apples, and on canned slice quality. (1956–57 season, Common storage).

Variety	Pressure test (lbs.)	Shear-press (lbs. force)	pH	Titratable acidity (per cent)	Ascorbic acid (mg./100 gms.)	Soluble solids (per cent)	Total sugars (per cent)	Total solids (per cent)	AIS (per cent)	Total pectins (per cent)	Acid-soluble pectins (per cent)	Water-soluble pectins (per cent)
Stayman	10.75	225.0	3.54	0.58	4.70	16.55	10.24	18.63	2.94	0.576	0.425	0.153
Golden Del.	11.92	279.0	3.79	0.40	3.68	15.47	9.99	17.15	2.48	0.485	0.338	0.147
York Imp.	15.22	348.0	3.54	0.41	3.29	13.57	10.16	15.67	2.59	0.535	0.363	0.172
Rome Beauty	13.03	274.0	3.63	0.27	2.83	13.24	9.34	14.92	2.48	0.476	0.355	0.121
Jonathan	12.25	296.0	3.43	0.70	5.23	13.37	9.28	16.61	2.43	0.408	0.247	0.161
L.S.D. 5% level	0.75	35.0	0.04	0.04	0.85	0.56	0.61	0.44	0.17	0.045	0.065	0.020
L.S.D. 1% level	1.02	47.0	0.05	0.05	1.15	0.75	0.82	0.59	0.23	0.060	0.088	0.027

Variety	Sugar-acid ratio	Skin color Hunter L	Skin color Hunter ^{a}L	Skin color Hunter $+^{b}L$	Trim, core peel losses (per cent)	Weight loss storage (per cent)	Color canned slices	Wholeness canned slices	Firmness canned slices	Flavor canned slices	Overall quality canned slices
Stayman	29.47	37.3	+16.4	+ 9.1		6.41	6.1	4.9		6.1	5.1
Golden Del.	40.72	73.6	−11.9	+33.1		7.00	7.4	7.1		6.5	6.7
York Imp.	34.01	51.8	+ 9.8	+16.2		5.22	7.2	7.4		6.6	6.5
Rome Beauty	52.06	49.2	+12.4	+17.2		4.59	6.0	6.3		5.6	5.5
Jonathan	21.34	41.6	+16.8	+15.4		5.44	6.3	6.9		5.9	6.0
L.S.D. 5% level	2.91	2.4	3.5	1.5	N.S.	0.66	0.7	0.5	N.S.	0.5	0.7
L.S.D. 1% level	3.91	3.2	4.8	2.0	N.S.	0.90	0.9	0.7	N.S.	0.6	0.9

Skin color measurements by the Hunter Color and Color Difference meter gave a satisfactory measure of the red and yellow skin types. There were small differences in trim, core and peel losses among the varieties. These losses ranged from 27.5 to 32.0 per cent. Stayman and Golden Delicious were particularly susceptible to weight loss in storage, especially in common storage. Rome Beauty showed very little weight loss in cold storage and was significantly lower than most varieties in common storage.

Canned slices—The slices made from the individual varieties varied considerably in quality as shown in Tables 4, 5, and 6. York Imperial and Golden Delicious slices exhibited the highest color scores during the two year study. Northwest Greening received very low color scores. York Imperial was highly rated for wholeness with Golden Delicious, Jonathan and Rome ranking as the next best varieties. Stayman was scored as being poor in wholeness particularly when held in common storage. Northwest Greening, although firm as a fresh apple, did not exhibit good wholeness characteristics. York Imperial and Jonathan slices were scored as the firmest under the conditions of the study, Golden Delicious was intermediate, while Rome Beauty, Northwest Greening and Stayman were low in firmness. Flavor scores for the individual varieties were nearly identical, but York Imperial and Golden Delicious were usually numerically higher than the other varieties. A composite ranking of the apple varieties for the canned slices from the organoleptic evaluations was as follows: York Imperial, Golden Delicious, Jonathan, Rome Beauty, Stayman and Northwest Greening. Outstanding features for the three best varieties were: York Imperial, firm, whole, and bright color; Golden Delicious, whole and a bright golden color; Jonathan, high acidity, firm and golden color. For the other three varieties, Stayman was soft, Rome Beauty and Northwest Greening were generally low in all quality categories.

Duration of storage effect—Results of the duration of storage effect on physical characteristics, chemical constitutents of the raw apples and the canned slice quality for the two seasons are presented in Tables 7, 8, and 9. These values are means for each storage period including all varieties, maturities and storage types. These means included 10 treatments in the first season's study and 15 in the second.

Raw apples—There was a reduction in firmness with increased duration of storage, however, a slight reversal in this trend was noticed in apples held in storage for long periods of time. This was probably due to an excessive loss of moisture which made the apples tough and leathery.

Acidity decreased with increased duration of storage. Ascorbic acid dropped by about 50 per cent from 8.0—9.0 at harvest time to 3.0—4.0 mg/100 gms. at the time of the 1st sampling from storage. This may be a practical index for a processor to determine if apples upon delivery from the orchard were freshly harvested.

The greatest increases in total solids, sugars and soluble solids

occurred between samples taken at harvest and those determined after one period of cold or common storage.

Per cent of alcohol insoluble solids decreased most sharply between harvest and the first period of storage. This fraction, which includes pectins, starches and cellulosic substances appeared to be greatly depleted during this early storage period.

The pectic substances total, acid soluble and water soluble, declined with increasing duration of storage. All dropped by about 50 per cent from the levels present in the raw apple at time of harvest. Total pectins dropped from 0.7 to 0.35 per cent, acid soluble 0.5 to 0.25 per cent and water soluble 0.2 to 0.1 per cent. The water soluble fraction showed slight increases after long storage periods during the 1955–56 season.

Per cent trim, core, and peel losses increased slightly with increased duration of storage in the cold storage fruit in 1956–57. The per cent weight loss by the fresh apples in storage varied from 0 to 4 per cent in cold storage and from 0 to 7.5 per cent in common storage.

Canned slices—Results for canned slices are also shown in Tables 7, 8, and 9. The color of the canned slices was improved if processed from apples held for a short storage rather than from those immediately after harvest (Table 7). Mean color scores in 1956–57 were lower in slices made from apples held for long periods in storage. Pre-optimum (early harvest) apples, however, showed a trend similar to those in the 1955–56 season. Color of samples made from apples held in storage until March were rated as inferior to the shorter storages.

The wholeness factor of canned slices was more satisfactory when the apples were held for a short storage than if processed immediately after harvest in 1955–56. In the second season, wholeness of the processed slices declined with the use of apples from increasing lengths of storage. Canned slices made from apples held in common storage showed the greatest decreases in wholeness. The range in wholeness scores was from 8.6 for freshly harvested samples to 5.1 for samples held for the full storage period. In firmness, a textural factor closely related to wholeness, apple slices processed from apples at the time of harvest received slightly lower scores than those from apples held for a short period prior to processing. These lower scores resulted because of a tough or rubbery condition in the slices. Slices made from apples held for 1 or 2 periods of storage received the highest firmness scores. Those made from apples held for long periods in storage received lower scores because they were slightly too soft.

In the 1955–56 season and with the common storage fruit in 1956–57 there were no significant differences among the canned samples in flavor. In 1956–57 lower flavor scores were given samples made from apples held for long periods in cold storage. The overall grade of canned slices showed slight differences between the seasons. In 1955–56 the overall scores of canned slices made from apples of the short storage periods were higher than the samples canned at harvest,

Table 7.—Effect of storage duration on physical characteristics, chemical constituents (fresh weight basis) of raw apples, and on canned slice quality. (1955–56 season).

Storage duration	Pressure test (lbs.)	Shear-press (lbs. force)	pH	Titratable acidity (per cent)	Ascorbic acid (mg./100 gms.)	Soluble solids (per cent)	Total sugars (per cent)	Total solids (per cent)	AIS (per cent)	Total pectins (per cent)	Acid-soluble pectins (per cent)	Water-soluble pectins (per cent)
As harvested	20.75	762.4		0.44	8.55	9.7	10.12	13.94	3.04	0.658	0.471	0.186
1 period	17.56	500.8		0.44	3.89	12.8	11.26	15.22	2.74	0.477	0.327	0.150
2 periods	15.02	380.1		0.41	2.06	13.3	11.35	15.07	2.54	0.401	0.257	0.144
3 periods	14.07	329.4		0.39	1.48	13.7	11.45	15.17	2.43	0.413	0.257	0.156
4 periods	12.38	333.4		0.36	1.13	13.1	11.57	15.08	2.32	0.391	0.226	0.165
L.S.D. 5% level	1.16	56.5	N.S.	0.04	1.01	1.0	0.82	0.80	0.21	0.052	0.042	0.017
L.S.D. 1% level	1.60	77.8	N.S.	0.06	1.39	1.4	1.12	N.S.	0.29	0.072	0.059	0.023

Storage duration	Sugar-acid ratio	Skin color Hunter L	Skin color Hunter ^{a}L	Skin color Hunter $+^{b}L$	Trim, core peel losses (per cent)	Color canned slices	Wholeness canned slices	Firmness canned slices	Flavor canned slices	Overall quality canned slices
As harvested	23.43		+0.52							
1 period	29.18		+3.49			5.4	6.4	6.3		5.4
2 periods	33.49		+3.00			6.2	7.4	6.6		6.1
3 periods	37.74		+4.65			5.8	7.3	6.6		5.8
4 periods	40.26		+4.56			5.5	6.8	6.4		5.6
L.S.D. 5% level	3.95	N.S.	2.48	N.S.	N.S.	5.6	6.2	5.9		5.3
L.S.D. 1% level	5.45	N.S.	N.S.	N.S.	N.S.	0.4	0.4	0.3	N.S.	0.4
						0.5	0.5	0.4	N.S.	0.5

Table 8.—Effect of storage duration on physical characteristics, chemical constituents (fresh weight basis) of raw apples, and on canned slice quality. (1956–57 season Cold storage).

Storage duration	Pressure test (lbs.)	Shear-press (lbs. force)	pH	Titratable acidity (per cent)	Ascorbic acid (mg./100 gms.)	Soluble solids (per cent)	Total sugars (per cent)	Total solids (per cent)	AIS (per cent)	Total pectins (per cent)	Acid-soluble pectins (per cent)	Water-soluble pectins (per cent)
As harvested	17.35	537.0	3.46	0.58	9.74	13.47	8.67		3.37	0.738	0.535	0.204
1 period	15.54	392.0	3.49	0.54	4.95	14.34	9.62		2.72	0.521	0.378	0.142
2 periods	12.88	261.0	3.55	0.50	3.54	14.90	10.69		2.45	0.455	0.346	0.116
3 periods	11.83	222.0	3.58	0.45	3.06	14.87	10.66		2.35	0.407	0.283	0.126
4 periods	11.41	194.0	3.64	0.41	2.46	15.22	11.23		2.35	0.385	0.275	0.111
L.S.D. 5% level	0.71	12.0	0.02	0.02	0.73	0.52	0.35	N.S.	0.13	0.057	0.065	0.020
L.S.D. 1% level	0.95	16.0	0.03	0.03	0.98	0.70	0.46	N.S.	0.17	0.077	0.088	0.027

Storage duration	Sugar-acid ratio	Skin color Hunter L	Skin color Hunter ^{a}L	Skin color Hunter $+^{b}$L	Trim, core peel losses (per cent)	Weight loss storage (per cent)	Color canned slices	Wholeness canned slices	Firmness canned slices	Flavor canned slices	Overall quality canned slices
As harvested	25.93	46.4	+7.9		29.1	0.00	7.3	8.6	7.9	6.3	6.9
1 period	30.27	49.1	+7.1		28.9	0.75	6.7	7.5	8.5	6.2	6.6
2 periods	32.89	51.4	+4.2		28.1	1.57	6.9	6.6	8.2	6.3	6.3
3 periods	36.69	53.9	+3.8		31.0	2.73	6.7	6.1	7.3	6.1	5.7
4 periods	43.36	52.3	+5.7		32.4	3.97	5.8	6.3	7.5	5.6	5.5
L.S.D. 5% level	3.01	2.7	2.4	N.S.	2.9	1.05	0.7	0.5	0.7	0.4	0.7
L.S.D. 1% level	4.05	3.6	3.3	N.S.	N.S.	1.43	0.9	0.7	N.S.	N.S.	0.9

Table 9.—Effect of storage duration on physical characteristics, chemical constituents (fresh weight basis) of raw apples, and on canned slice quality. (1956–57 season Common storage).

Storage duration	Pressure test (lbs.)	Shear-press (lbs. force)	pH	Titratable acidity (per cent)	Ascorbic acid (mg./100 gms.)	Soluble solids (per cent)	Total sugars (per cent)	Total solids (per cent)	AIS (per cent)	Total pectins (per cent)	Acid-soluble pectins (per cent)	Water-soluble pectins (per cent)
As harvested	16.68	537.0	3.46	0.58	9.74	13.47	8.76		3.37	0.738	0.535	0.204
1 period	13.21	292.0	3.55	0.52	4.01	14.67	9.51		2.50	0.464	0.321	0.144
2 periods	11.31	216.0	3.60	0.44	2.35	14.74	10.52		2.40	0.436	0.299	0.137
3 periods	10.63	123.0	3.65	0.42	1.85	14.98	10.35		2.33	0.403	0.266	0.138
4 periods	10.67	187.0	3.66	0.40	1.87	15.33	9.86		2.32	0.437	0.307	0.131
L.S.D. 5% level	0.75	35.0	0.04	0.04	0.85	0.56	0.61	N.S.	0.17	0.045	0.065	0.020
L.S.D. 1% level	1.02	47.0	0.05	0.05	1.15	0.75	0.82	N.S.	0.23	0.060	0.088	0.027

Storage duration	Sugar-acid ratio	Skin color Hunter L	Skin color Hunter ^{a}L	Skin color Hunter $+^{b}L$	Trim, core peel losses (per cent)	Weight loss storage (per cent)	Color canned slices	Wholeness canned slices	Firmness canned slices	Flavor canned slices	Overall quality canned slices
As harvested	29.93	46.4		+16.5		0.00	7.3	8.6			6.9
1 period	30.61	47.9		+17.6		3.54	6.8	6.8			6.3
2 periods	37.80	51.3		+18.6		5.19	6.5	6.0			5.8
3 periods	40.48	53.6		+18.8		6.57	6.2	6.0			5.7
4 periods	42.70	54.4		+19.5		7.62	6.2	5.1			5.1
L.S.D. 5% level	2.91	2.4	N.S.	1.5	N.S.	0.59	0.7	0.5	N.S.	N.S.	0.7
L.S.D. 1% level	3.91	3.2	N.S.	2.0	N.S.	0.81	0.9	0.7	N.S.	N.S.	0.9

or after long storage. In the 1956–57 season overall scores of apple slices progressively decreased as storage of the fruit was prolonged. The differences in trends here can probably be attributed to the fact that the apples in the 1955–56 season were an optimum harvest while data for the storage duration effects in 1956–57 include mean values of three maturity levels.

Storage type effect—Results of the type of storage (cold or common) on the physical characteristics, chemical constituents of raw apples and canned slice quality for two seasons 1955–56 and 56–57 are presented in Table 10. Values are means for each storage type including all varieties, maturities and storage durations. In the 1955–56 season each determination includes 25 treatments and in the 1955–56 season 75 treatments. No attempt was made to make a statistical comparison of means in the 1956–57 season because of the complexity of analysis.

Raw apples and canned slices—In 1955–56 raw apples and processed slices from apples taken from either cold or common storage were not significantly different in physical characteristics, chemical constituents and most quality attributes as shown in Table 10. Temperature accumulations in common storage expressed in degree/days above a 30°F base line for the 1955–56 season were as follows: September 15 to September 30, 373; to October 31, 940; to November 30, 1179 degree days. For the period from September 15 to November 30, apples held in cold storage had accumulated about 310 degree/days above 30°F.

In 1956–57, the apples held in common storage ripened more quickly and were generally lower in quality for processing than apples from cold storage. Temperature accumulations, expressed in degree/days above 30°F base line for the 1956–57 season were as follows: September 15 to September 30, 430; to October 31, 1163; to November 30, 1465 degree/days. Cold storage apples during the same time interval had only received about 20 per cent as many heat units above 30°F. In 1956–57 apples held in common storage had received by October 31 as many heat units as were received in the previous season by November 30. Raw quality factors indicated the apples taken from common storage were riper than those taken from cold storage. Canned slice quality scores showed that slices made from apples held in cold storage prior to processing received higher values.

Maturity effect—Results of the maturity effect on the physical characteristics, chemical constituents of raw apples and canned slice quality for the 1956–57 season are shown in Tables 11 and 12. Values presented are means for each harvest including all varieties, storage types and storage durations. Each figure in the tables represents the mean of 25 different treatments.

Raw apples—Early, medium and late harvested apples exhibited differences in firmness with the more mature apples being less firm as shown in Tables 11 and 12. Other chemical constituents showed trends similar to those of apples ripening in storage. The pH in-

Table 10.—Effect of storage type on physical characteristics, chemical constituents (fresh weight basis) of raw apples, and on canned slice quality. (1955–56, 1956–57 seasons).

Storage type	Pressure test (lbs.)	Shear-press (lbs. force)	pH	Titratable acidity (per cent)	Ascorbic acid (mg./100 gms.)	Soluble solids (per cent)	Total sugars (per cent)	Total solids (per cent)	AIS (per cent)	Total pectins (per cent)	Acid-soluble pectins (per cent)	Water-soluble pectins (per cent)
1955–56												
Common												
Cold												
L.S.D. 5% level	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
L.S.D. 1% level	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
1956–57												
Common	12.63	284.0	3.59	0.47	3.95	14.63	9.80	16.60	2.58	0.496	0.346	0.151
Cold	13.80	321.0	3.55	0.50	4.75	14.56	10.19	16.55	2.65	0.501	0.363	0.140

Storage type	Sugar-acid ratio	Skin color Hunter L	Skin color Hunter [a]L	Skin color Hunter +[b]L	Trim, core peel losses (per cent)	Weight loss storage (per cent)	Color canned slices	Wholeness canned slices	Firmness canned slices	Flavor canned slices	Overall quality canned slices
1955–56											
Common				+22.2			5.8	6.6			
Cold				+21.1			5.5	6.9			
L.S.D. 5% level	N.S.	N.S.	N.S.	0.9	N.S.		0.2	0.2	N.S.	N.S.	N.S.
L.S.D. 1% level	N.S.	N.S.	N.S.	1.0	N.S.		N.S.	N.S.	N.S.	N.S.	N.S.
1956–57											
Common	35.53	50.7	+8.7	+18.2	31.6	5.73	6.6	6.5	7.4	6.1	6.0
Cold	33.83	50.6	+5.7	+16.5	29.9	2.25	6.7	7.1	7.9	6.1	6.2

Table 11.—Effect of maturity on physical characteristics, chemical constituents (fresh weight basis) of raw apples, and on canned slice quality. (1956–57 season Cold storage).

Maturity	Pressure test (lbs.)	Shear-press (lbs. force)	pH	Titratable acidity (per cent)	Ascorbic acid (mg./100 gms.)	Soluble solids (per cent)	Total sugars (per cent)	Total solids (per cent)	AIS (per cent)	Total pectins (per cent)	Acid-soluble pectins (per cent)	Water-soluble pectins (per cent)
Early	14.96	364.0	3.47	0.54		13.93	9.40	16.19	2.95	0.585	0.412	0.174
Medium	13.40	308.0	3.55	0.49		14.87	10.61	16.78	2.63	0.481	0.355	0.133
Late	13.04	292.0	3.62	0.45		14.88	10.57	16.69	2.36	0.436	0.323	0.113
L.S.D. 5% level	0.55	9.0	0.02	0.02	N.S.	0.48	0.27	0.26	0.09	0.045	0.041	0.020
L.S.D. 1% level	0.74	12.0	0.03	0.03	N.S.	0.65	0.37	0.36	0.12	0.060	0.055	0.027

Maturity	Sugar-acid ratio	Skin color Hunter L	Skin color Hunter ^{a}L	Skin color Hunter $+^{b}$L	Trim, core peel losses (per cent)	Weight loss storage (per cent)	Color canned slices	Wholeness canned slices	Firmness canned slices	Flavor canned slices	Overall quality canned slices
Early	29.10	54.8	−1.3	+18.3	28.5		6.4	6.8		5.8	5.8
Medium	34.18	49.0	+ 8.3	+15.8	28.4		6.8	6.9		6.1	6.2
Late	38.20	48.1	+10.2	+15.3	32.8		7.1	7.4		6.4	6.6
L.S.D. 5% level	2.33	2.1	1.9	1.0	3.2	N.S.	0.5	0.4	N.S.	0.3	0.5
L.S.D. 1% level	3.13	2.8	2.5	1.4	3.0	N.S.	N.S.	N.S.	N.S.	0.5	N.S.

Table 12.—Effect of maturity on physical characteristics, chemical constituents (fresh weight basis) of raw apples, and on canned slice quality. (1956–57 Common storage).

Maturity	Pressure test (lbs.)	Shear-press (lbs. force)	pH	Titratable acidity (per cent)	Ascorbic acid (mg./100 gms.)	Soluble solids (per cent)	Total sugars (per cent)	Total solids (per cent)	A.I.S. (per cent)	Total pectins (per cent)	Acid-soluble pectins (per cent)	Water-soluble pectins (per cent)
Early	13.65	323.0	3.52	0.05		13.71	8.86	16.08	2.74	0.541		0.176
Medium	13.22	263.0	3.58	0.49		15.05	9.99	16.78	2.64	0.502		0.157
Late	12.03	268.0	3.66	0.43		15.15	10.55	16.94	2.37	0.445		0.119
L.S.D. 5% level	0.59	21.0	0.03	0.03	N.S.	0.43	0.47	0.34	0.13	0.035	N.S.	0.020
L.S.D. 1% level	0.79	34.0	0.04	0.04	N.S.	0.57	0.63	0.46	0.17	0.047	N.S.	0.027

Maturity	Sugar-acid ratio	Skin color Hunter L	Skin color Hunter ^{a}L	Skin color Hunter $+^{b}L$	Trim core peel losses (per cent)	Weight loss storage (per cent)	Color canned slices	Wholeness canned slices	Firmness canned slices	Flavor canned slices	Overall quality canned slices
Early	29.97	54.1	+ 3.7	+20.5		5.12	6.3				
Medium	35.45	48.7	+11.7	+17.2		6.00	6.6				
Late	41.14	49.4	+10.7	+16.9		6.09	6.9				
L.S.D. 5% level	2.26	1.8	2.7	1.1	N.S.	0.46	0.5	N.S.	N.S.	N.S.	N.S.
L.S.D. 1% level	3.03	2.5	3.7	1.5	N.S.	0.63	N.S.	N.S.	N.S.	N.S.	N.S.

Table 13.—Single correlation coefficients between raw apple quality measurements and canned slice quality. 1956–57 Season.

Variety	Finished product factors	% total solids	pH	% titratable acidity	% ascorbic acid	Pressure test	Shear press	% soluble solids	S/A ratio[a]
Stayman	overall	+.089	−.245	+.612	+.504	+.586	+.747	−.327	−.669
	wholeness	+.054	−.405	+.753	+.616	+.739	+.845	−.237	−.574
	firmness	+.018	−.441	+.699	+.581	+.822	+.864	−.344	−.613
	color	+.241	−.333	+.507	+.424	+.515	+.673	−.038	−.289
	flavor	+.107	+.095	+.301	+.217	+.152	+.293	+.075	−.079
G. Del	overall	−.348	−.608	+.662	+.185	+.697	+.714	−.634	−.646
	wholeness	−.511	−.731	+.611	+.181	+.767	+.744	−.739	−.756
	firmness	−.335	−.731	+.645	+.280	+.873	+.863	−.712	−.731
	color	−.139	−.135	+.147	+.038	+.120	+.063	−.253	−.189
	flavor	−.178	−.404	+.289	+.286	+.437	+.354	−.381	−.388
York Imp	overall	+.239	−.219	+.370	+.523	+.437	+.436	−.129	−.332
	wholeness	+.202	−.098	+.230	+.512	+.536	+.553	−.367	−.176
	firmness	+.425	−.314	+.448	+.681	+.777	+.792	−.470	−.402
	color	+.223	−.104	+.327	+.503	+.447	+.525	−.222	−.291
	flavor	+.040	−.409	+.444	−.236	+.138	+.127	−.145	−.473
R. Beauty	overall	+.068	−.457	+.375	+.542	+.725	+.725	−.408	−.464
	wholeness	+.002	−.473	+.260	+.689	+.701	+.683	−.350	−.406
	firmness	+.070	−.275	+.516	+.665	+.580	+.641	+.013	−.377
	color	−.081	−.501	+.565	+.487	+.391	+.639	−.298	−.654
	flavor	−.092	−.409	+.292	+.421	+.222	+.464	−.608	−.537
Jonathan	overall	+.150	+.367	−.212	+.256	−.251	+.008	+.396	+.352
	wholeness	+.075	−.052	+.162	+.596	+.263	+.546	+.193	−.193
	firmness	+.222	−.380	+.465	+.798	+.603	+.816	+.109	−.385
	color	+.264	+.351	−.212	+.063	−.186	+.044	+.473	+.382
	flavor	+.106	+.337	−.450	−.169	−.525	−.327	+.437	+.483

[a]Soluble solids/acid ratio.

creased, acidity decreased, soluble solids, total solids and total sugars increased, AIS and pectic constituents decreased. Post-optimum or late maturity apples showed the greatest trim, peel, core and weight losses.

Canned slices—Color, wholeness, flavor and overall scores of slices increased with the use of apples of more advanced maturity as shown in Tables 11 and 12. Except for the factor of firmness, the more mature the apple was at the time of processing the higher the quality of the canned product. This was especially true if processing occurred immediately after harvest and not after periods of cold or common storage.

Raw product—slice quality relationships

No attempt will be made to discuss each individual correlation coefficient covered in these results, only the most pertinent findings will be presented.

Raw quality measurements and slice quality factors—Data from the 1956–57 season were used for determination of the correlation coefficients between raw quality measurements and canned slice organoleptic evaluations. The single correlation coefficients for the major raw product measurements with processed product evaluations are presented in Tables 13 and 14. Stayman, Golden Delicious

Table 14.—Single correlation coefficients between raw, processed slice quality factors and the various pectic constituents. 1956–57.

Variety	Pectic constituents	Wholeness	Firmness	Shear-press
Stayman	total pectins	+.575	+.691	+.863
	WS pectins[a]	+.211	+.327	+.604
	AS pectins[b]	+.693	+.776	+.861
Golden Delicious	total pectins	+.223	+.433	+.407
	WS pectins	+.274	+.368	+.400
	AS pectins	+.366	+.268	+.277
York Imperial	total pectins	+.456	+.493	+.849
	WS pectins	+.058	+.078	+.613
	AS pectins	+.548	+.516	+.810
Rome Beauty	total pectins	+.256	+.324	+.360
	WS pectins	+.085	+.038	+.092
	AS pectins	+.306	+.265	+.216
Jonathan	total pectins	+.469	+.667	+.720
	WS pectins	−.145	+.014	+.232
	AS pectins	+.621	+.770	+.748

[a]Water soluble pectins.
[b]Acid soluble pectins.

and Rome Beauty, as compared with York Imperial and Jonathan, showed relatively high correlation coefficients between raw quality measurements and finished product quality. Overall grade, wholeness and firmness of these varieties were more closely associated with raw product tests than either color or flavor. Of the raw quality factors studied titratable acidity, abscorbic acid, pressure test, shear-press and sugar-acid ratio appeared the most promising as single tests to predict apple slice quality.

The shear-press, which measures the textural properties of raw apples, showed a consistantly high correlation with firmness of the canned slices measured organoleptically. Fig. 1 presents the relationship between shear-press determinations on the raw apple and the firmness of the canned slices. The highly significant correlation coefficient of +0.828 indicated firmness of canned slices may be predicted directly from shear-press readings of raw apples. In this study, process temperatures and times were held constant for all maturity levels.

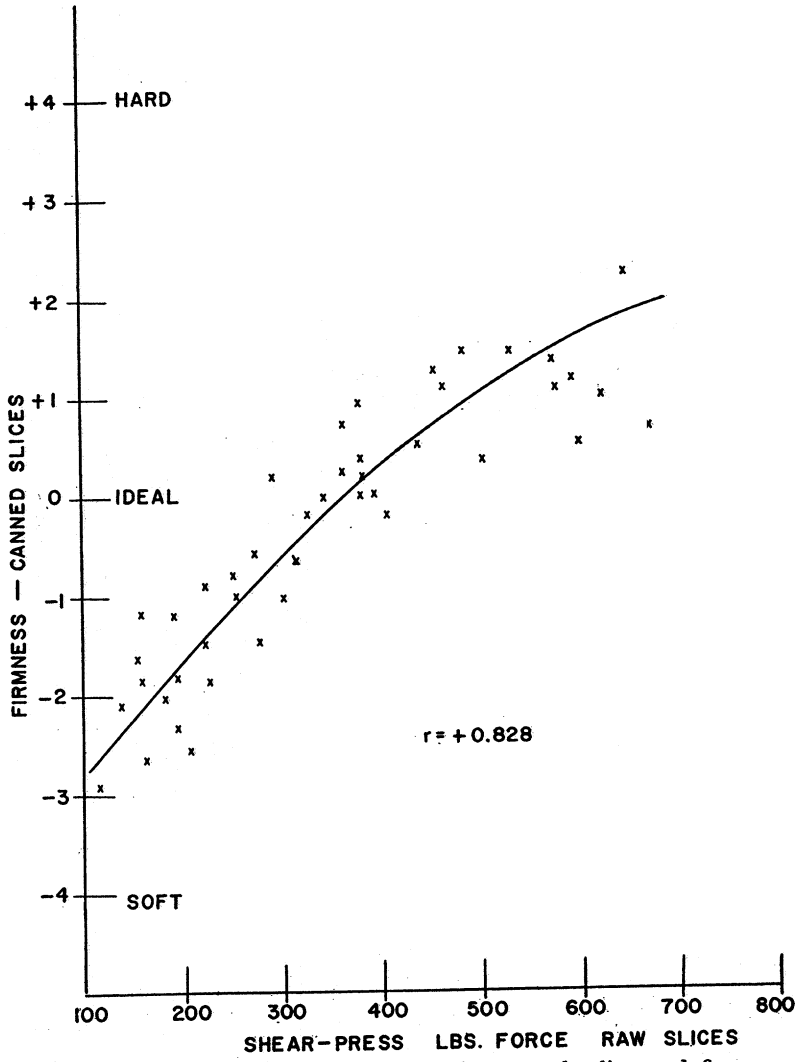

Fig. 1. Relationship between shear-press of raw apple slices and firmness of the canned product.

However, since processes vary considerably under commercial conditions, a multiple regression equation using raw product shear-press values and important process variables must be included for accurate prediction of canned slice firmness. Shear-press readings of 300–400 lbs. force on raw fruit gave the most acceptable canned slices from the standpoint of firmness.

Wholeness of canned slices, also appeared to be associated with shear-press determinations of the raw slices, however, the correlation (+0.734) was not as high as between firmness and raw shear-press determinations. The relationship between the two sets of values were distinctly logarithmic in nature. Cause for the lower correlation was undoubtedly the greater spread of points from the regression line at higher wholeness and shear-press values. Optimum firmness of the raw apples of 300–400 lbs-force also gave wholeness scores in the fancy area ranging from 7.0 to 8.5.

Slice texture (Table 14)—In raw apples the total pectin content appeared to be closely related to shear-press determinations of raw slices, particularly in the Stayman, York Imperial and Jonathan varieties. The acid soluble fraction also appeared to be closely related to firmness in these varieties. At the same time pectic substances of Rome Beauty and Golden Delicious showed little relationship to firmness of the raw apple. There appeared to be very definite varietal differences in the pectic substance-raw slice firmness relationships. The water soluble fraction had practically no influence on the firmness of raw slices. It appeared that additional substances were influencing the firmness of raw slices both freshly harvested and out of storage, especially in Rome Beauty and Golden Delicious.

In the canned slice it appeared that firmness and wholeness were more closely related to the acid soluble pectin fraction than either the total or water soluble fractions in Stayman, York Imperial and Jonathan. In Rome and Golden Delicious no one pectic fraction appeared very closely associated with wholeness and firmness. Further the water soluble fraction did not appear closely associated with the textural properties of slices made from any of the varieties studies. Again varieties appeared to segregate into two groups, those where pectic substances play an important role in texture and those where pectic substances play a minor role.

Quality tests (Table 15)—No one raw quality test was closely associated with the overall grade of the canned slices. It was decided to select the most practical quick tests which had reasonably high single correlation coefficients with the overall grade of canned slices and combine then in multiple regression equations. The raw product tests which showed the greatest promise were titratable acidity, shear-press and soluble solids. The sugar-acid ratio was not as efficient as using titratable acid and soluble solids singly in the equations. These three raw product tests used on Stayman, Golden Delicious and Rome Beauty accounted for about 65 per cent of the variation in overall grade scores of the canned slices. This was a multiple correlation of 0.8. Table 15 presents the multiple correlations and the multiple regression equations for overall scores of canned slices

Table 15.—Multiple correlation coefficients and coefficients of determination between over-all slice scores and certain raw product quality factors by variety. 1956–57.

	R^2	R	Quality factors
Stayman	.658	.811	Shear press–Titratable acidity–Soluble solids
Golden Delicious	.587	.766	Shear press–Titratable acidity–Soluble solids
Rome Beauty	.656	.810	Shear press–Titratable acidity–Soluble solids
York Imperial	.211	.460	Shear press–Titratable acidity
Jonathan	.364	.604	Soluble solids–pH–Hunter b

Multiple regression equations for 1st three varieties
Stayman over-all grade slices = −1.47 + .011 SP + 5.11 T.A. + .074SS.
Golden Delicious over-all grade slices = 8.51 + .002SP + 4.74 T.A. + .286SS.
Rome Beauty over-all grade slices = 11.53 + .006SP + 4.75 T.A. − .559SS.

and the three raw product tests. These multiple correlations have improved the best single correlations from 0.7 to 0.8. The multiple regression equations can be used to predict overall grade by substituting actual values for each factor in the equation. This is a general equation and would have to be considered specific for the processes used in this study and relatively precise when used for the various commercial processes. York Imperial and Jonathan did not fit into the suggested multiple regression system for determining overall grade for unknown reasons. Multiple correlations developed with all possible combinations of raw product tests using these two varieties, could not account for more than 21 to 36 per cent of the variation in overall grade scores.

Canned slice quality relationships 1955–56 season (Table 16)—These correlations coefficients were derived from the organoleptic panel scores of the industry group. Results showed color of the processed slices had a great influence on the overall grade assigned to the samples. All factors when combined in a multiple relationship accounted for 98.7 per cent of the variation in overall scores.

By determination of the partial regression correlation coefficient (b values) and summating them, the approximate weight each quality factor contributed in terms of overall grade was determined. In Table 17 are presented the percentages attributed to each quality factor. Color is the principle factor followed by firmness, flavor and wholeness. If wholeness and firmness were combined into the factor texture the per cent valuation of each would be color 45, texture 40 and flavor 15 per cent.

1956–57 season (Table 16)—The highest single correlation coefficient was again between color and the overall grade scores. All factors combined in a multiple correlation with the overall scores i.e. wholeness, firmness, color and flavor accounted for 93.7 per cent of the variation in overall scores. The multiple correlation of 0.968 showed great improvement over the single correlation coefficient of +0.763 between color and overall grade scores. The same pattern was shown as in the previous season with a 0.70 or higher correlation between wholeness and firmness and between color and flavor.

In Table 17 the partial multiple regression coefficients (b value) showed an emphasis of 45 per cent for color, 50 per cent for texture (wholeness and firmness combined) and 5 per cent for flavor.

Table 16.—Simple and multiple correlations between apple slice quality factors.

Quality factors	1955–56	1956–57
	r	r
Wholeness vs overall quality	+.661	+.756
Firmness vs overall quality	+.804	+.658
Color vs overall quality	+.933	+.763
Flavor vs overall quality	+.269	+.673
Wholeness vs firmness	+.820	+.749
Wholeness vs color	+.424	+.243
Wholeness vs flavor	+.382	+.375
Firmness vs color	+.486	+.391
Firmness vs flavor	+.583	+.375
Color vs flavor	+.895	+.731
R^2	.987	.937
R	.993	.968

Table 17.—Approximate relative importance of slice quality factors when related to overall quality scores.

	1955–56	1956–57
Color	46.4%	45.5%
Wholeness	7.6%	47.1%
Firmness	31.2%	6.2%
Texture[a]	(38.8%)	(53.3%)
Flavor	14.8%	1.2%

[a]Totals for wholeness and firmness.

Summary and Conclusions

The following conclusions may be drawn from the results of this two year study:

1. Varieties for canned slices ranked on the basis of over-all grade, as follows: York Imperial, Golden Delicious, Jonathan, Stayman, Rome Beauty, and Northwest Greening. Individual quality factors accounting for their ranking were: York Imperial firm, whole, bright color; Golden Delicious, whole, particularly early harvest, and bright color; Jonathan, firm, whole from cold storage, and golden color; Stayman, soft, tendency to slough, and dull color; Rome Beauty low in all quality factors; Northwest Greening, low in all quality factors, particularly color.

2. Storage types i.e., cold or common storages were approximately the same in their affects on slice quality when common storage periods were about half the cold storage periods. Length of common storage, however, should be carefully regulated according to seasonal temperatures and the apples held in this manner should be processed prior to excessive heat unit accumulations.

3. Length of time the raw apples remained in storage had a pronounced effect on the canned slice quality. Apples harvested in the early maturity range required a short period of storage before making canned slices of maximum quality. Firmness of slices was greatly improved by short storage in these apples with the change being from a tough and rubbery product to one of more ideal firmness.

Slices made from apples harvested at a medium or late harvest declined in quality as the raw apples were held for increasing periods

of time prior to processing. Slices manufactured from raw apples held in storage until February or March were lacking in firmness and were dull in color.

4. Maturity of the apples at harvest had an important effect on the canned slice quality. Slices made from the apples of a post-optimum maturity gave the highest quality ratings, especially if processed immediately after harvest. The factors of color, wholeness, flavor and overall grade improved with increasing maturity, while ideal firmness was found in early harvest apples which had ripened slightly in storage. It appears that color, flavor, and wholeness must be sacrificed in sliced apples to obtain proper firmness.

5. No one chemical or physical measurement of the raw apple as harvested or as taken from storage appeared fully satisfactory for predicating the overall grade of canned slices. Of single tests, titratable acidity, shear-press, soluble solids, and sugar-acid ratio appeared to be most important. Combining these factors into one predication equation gave a more satisfactory estimate of over-all grade. Stayman, Golden Delicious, and Rome Beauty lent themselves to this system, with each variety requiring a slightly different equation. These equations have been fashioned to apply as a pre-test in the orchard or at the time or receipt, for segregation in cold storage or on the yard, or for apples as removed from storages. This information can be used as a guide for process control in the manufacturing plant.

6. The shear-press, an instrument which was used to measure the textural properties of raw apple slices, showed promise as a predicator of canned slice firmness and wholeness. Determinations of firmness by this instrument appeared satisfactory for all varieties. Raw slices in the 300–400 lbs-force range gave canned slices with the most ideal firmness and wholeness. It should be emphasized, however, that processing treatments will have an influence on the firmness of the canned slices and this should be considered in determining the most acceptable firmness ranges of the raw apples.

7. About 96 per cent of the variation in the over-all grade of canned apple slices was accounted for by the quality factors of color, wholeness, firmness, and flavor. From the partial regression coefficients it was determined that color accounted for about 45 per cent, wholeness and firmness (combined as texture) 47.5 per cent, and flavor 7.5 per cent of the over-all grade. Results of the judges evaluations indicated that most quality emphasis in canned apple slices should be centered in the texture and color areas.

8. Pectic constituents, expressed as anhydrogalacturonic acid, of the varieties showed significant differences and ranged from .3 per cent for Rome Beauty to .6 per cent for Stayman. In many cases both the firm and soft varieties contained approximately equal amounts of the pectic constituents, thus it appeared that other fractions of the AIS were also making a substantial contribution to firmness differences.

9. Pectic content of apple varieties held in common or cold storage were not significantly different, however, the length of time held

in storage had an important affect on the pectic constituents. In the periods of storage studied the total, acid soluble and water soluble pectins decreased by about 50 per cent. The largest drop was found during the 1st increment of storage. No important increases in water soluble pectins were determined in raw apples taken from storage as late as February or March.

10. The pectic content of raw apples of the various maturity levels were significantly different, with the early maturity apples exhibiting the highest amounts of the total, acid, and water soluble pectic constituents.

11. A correlation coefficient of about + 0.80 was found between shear-press determinations of the raw slices, when harvested and when removed from storage, and the total pectins of the Stayman, York Imperial and Jonathan varieties. Relationships between the firmness of the raw slices and pectic substances of the other varieties studied did not yield such high relationships.

12. Firmness and wholeness of the canned slices appeared to be more closely related to the acid soluble pectins rather than either the total or water soluble components. Again there were differences among varieties with Stayman, York Imperial, and Jonathan exhibiting the highest positive correlations while Rome Beauty and Golden Delicious showed lower relationships.

13. Pectic constituents of apples were generally associated with the textural properties of the raw and canned slices. Qualifications to this statement are: total pectins were more closely related to raw apple texture, while acid soluble pectins were more closely related to firmness and wholeness of the canned slices. These relationships held true for Stayman, York Imperial and Jonathan while in Rome Beauty and Golden Delicious other fractions of the AIS appeared to be of considerable importance in accounting for differences in texture.

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